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13. ABSTRACT *(Maximum 200 words)*

The Micropatch antenna is a ubiquitious entity which is more and more being used in arrays to form beams for communication from one point to another. To accomplish this one needs to be able to make the patch as flexible as possible. And at the same time be able to reliably form the beam of the antenna array. We have been looking at the ability of embedded element to adjust the phase shift seen by the element with the goal of being able to remove the phase shifting devices from the antenna and replace it wirh a phase shifting antenna element. This would reduce the number of components and connections associated with the array, and hopefully reduce loss associated with these extra devices. As part of this research we have discovered that the addition of controlling elements into the microstript patch has been able to shift the phase of the field in the far field to some extent. We have also discovered that there is not a consistent phase pattern in the far field from the element with respect to the azimuthal direction. This discovery was unsettling as this could be due to a movement of the phase center during the phase adjustment. To investigate this effect we set out in this final phase of this research activity to determine by modeling if there might be a change in phase center position with the change in bias of the controlling device that was embedded in the microstrip patch.

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Final Report

Airforce Office of Scientific Research

Micropatch Antenna Phase Shifting

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Abstract

The Micropatch antenna is a ubiquitous entity which is more and more being used in arrays to form beams for communication from one point to another. To accomplish this one needs to be able to make the patch as flexible as possible. And at the same time be able to reliably form the beam of the antenna array. We have been looking at the ability of embedded element to adjust the phase shift seen by the element wit the goal of being able to remove the phase shifting devices from the antenna and replace it with a phase shifting antenna element. This would reduce the number of components, and connections associated with the array, and hopefully reduce loss associated with these extra devices. As part of this research we have discovered that the addition of controlling elements into the microstrip patch has been able to shift the phase of the field in the far field to some extent. We have also discovered that there is not a consistent phase pattern in the far field from the element with respect to the azimuthal direction. This discovery was unsetteling as this could be due to a movement of the phase center during the phase adjustment. To investigate this effect we set out in this final phase of this research activity to determine by modeling if there might be a change in phase center position with the change in bias of the controlling device that was embedded in the microstrip patch.

Table ofContents

Introduction

The study of the microstrip patch antenna and the ability to control the characteristics of the patch using embedded impedance elements has resulted in the question of wether the change in characteristics and effective pointing angle of the patch is a result of phase center changes of the patch as an array. To this end we have undertaken the study of the phase center of the patch antenna with and without impedance elements embedded.

The model used for this investigation is that of a micro-strip patch antenna consisting of a radiation patch element supported by a dielectric layer, and placed on a ground-plane. The antenna is a standard element as described in the literature(1,2,3,4). In addition as has been developed in the Antenna Systems laboratory the insertion of a loading element as first suggested by Schaubert, and Long (5,6,7) has been used to alter the characteristics of the individual patch. Figure 1 and Figure 2 show the patch in its basic form and the addition of an impedance element for control of the antenna.

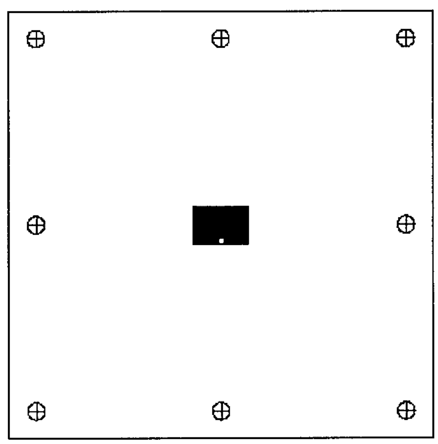


Figure 1 Standard patch layout.

The characteristics of the patch were;

- 425 mil wide (x-dimension) by 356 mil long (y dimension)
- Patch centered about the origin
- Probe fed, at 0, -85 mils
- Dielectric, Rogers 5880
    - Er= 2.2,
    - 62 mil thick
- Copper foil 1.34 mils thick

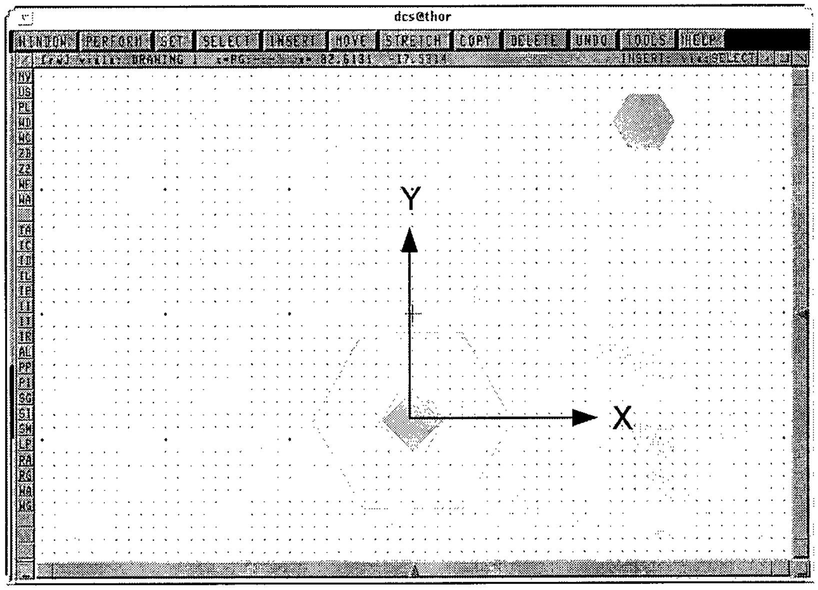


Figure 2 Standard patch modified to contain a impedance element for control of the characteristics.

The configuration shown is a general diagram of the test article, The actual location of the via was varied. The set of modeled values for via locations is given below. Measurements are in mils (0.001 “).

Test Configuration	Feed Location	Shorting Location
• Via1a feed	0, -85	pin 187.5,153
• Via2a feed	0,-85	pin 137,153
• Via3a feed	0,-85	pin 87.5,153
• Via5a feed	0,-85	pin0,153
• Via9a feed	0,-85	pin-187.5,153

In order to find the radiation center the model of the patch was moved within the framework of the simulator and then the far field phase was computed. The various positions that were investigated are delineated below.

Descriptor Geometry

- Cenpatch patch centered about x & y Back patch moved -85 mils y directionForword patch moved +85 mils y direction
- left patch moved +85 mils in x directionright patch moved -85 mils in x direction

If one considers a single point to represent the phased center, and that point can be move around s that the center of rotation moves in relation to tne point then the effect will be to modify the expression governing the far field phase of antenna in a predictable manner. Similarly if one finds a place where the far field phase does not change with azimuthal rotation of the antenna it can be inferred that the point of rotation coincides with the phase center at least in the plane of rotation. We have built a positioning table that was added to the measurement set-up to allow for such adjustment. Figure B shows a set of data taken from the measurement equipment demonstrating the dependence of the far-phase on the position of the phase center of the antenna.

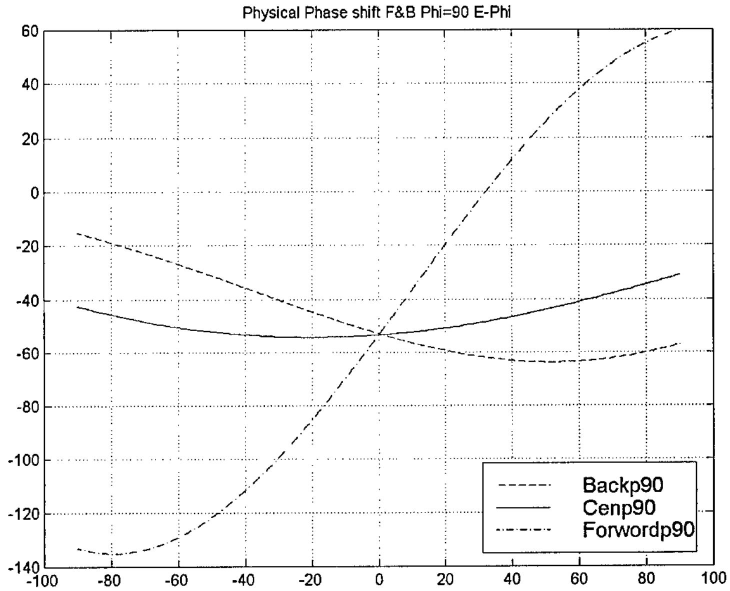


Figure 3 Phase variations with change in the position of the phase center within the plane of rotation.

The case called Forwordp90 represents the most dramatic demonstration of the effect. The case labeled Back90 also demonstrates the effect but to a much smaller extent. The trace labeled cenp90 is the best alignment and yet still represents a +/- 5 Degree variation in far field phase. This plot is when one rotates the antenna as to maintain constancy in the E-Phi planed. A similar set of data can be seen in the plot in figure B. The explanation of these graphs follows the same lines as described above.

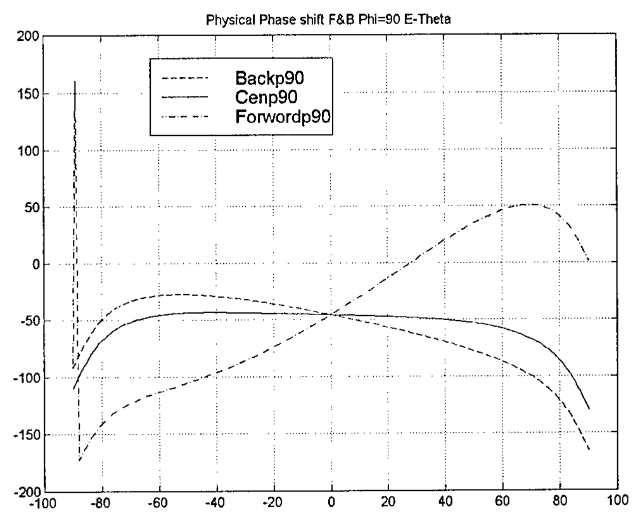


Figure 4 Phased variations in the E- /theta plane.

Again the Cenp90 position has the most constant phase over angle. This is then the position of the phase center in thes plane also.

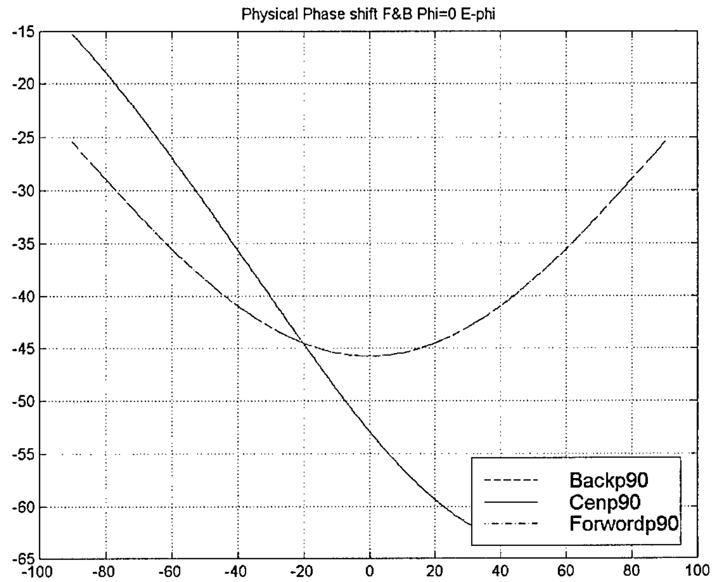


Figure 5 Ephi for phi = 0 plane

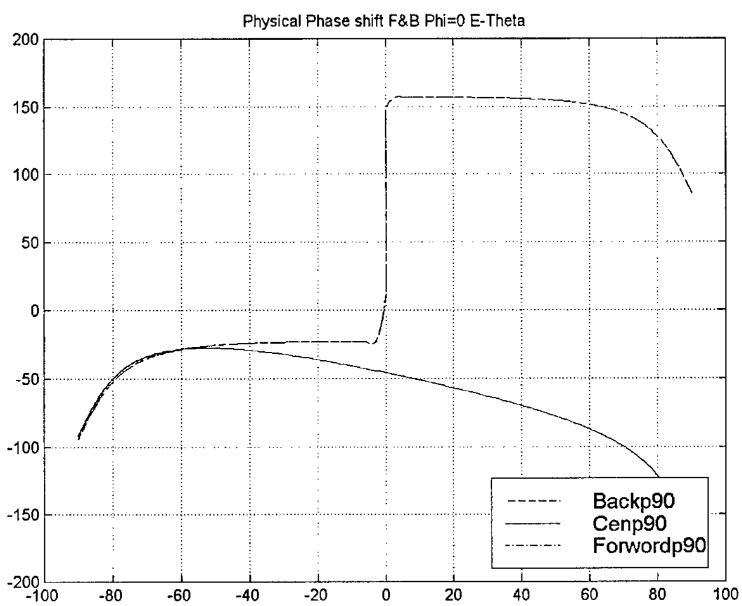


Figure 6 E theta for phi = 0 plane.

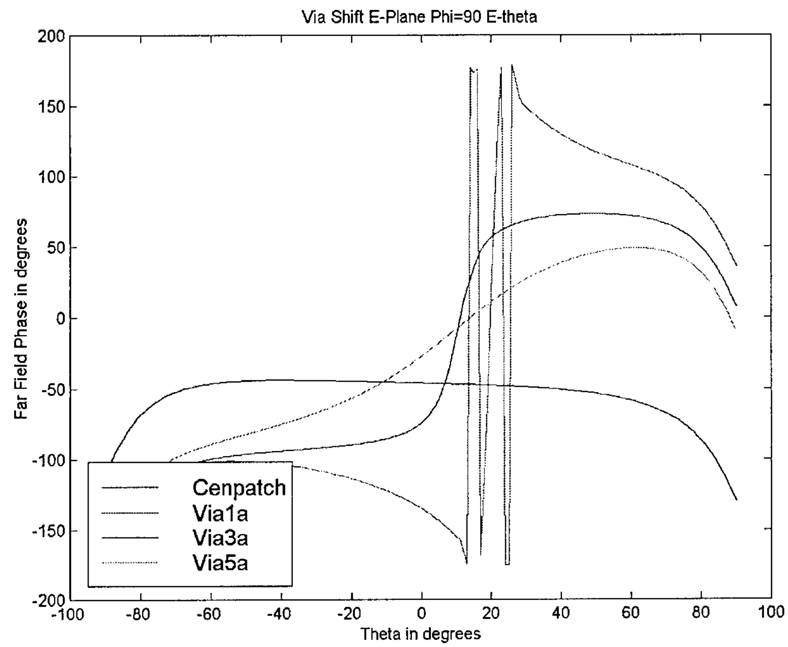


Figure 7 Far field phase variation for three different via locations

The variation of phase with vialocation seems to indicate that the phase center is moving with the addition of a via and that the via location alters the far field phase significantly.

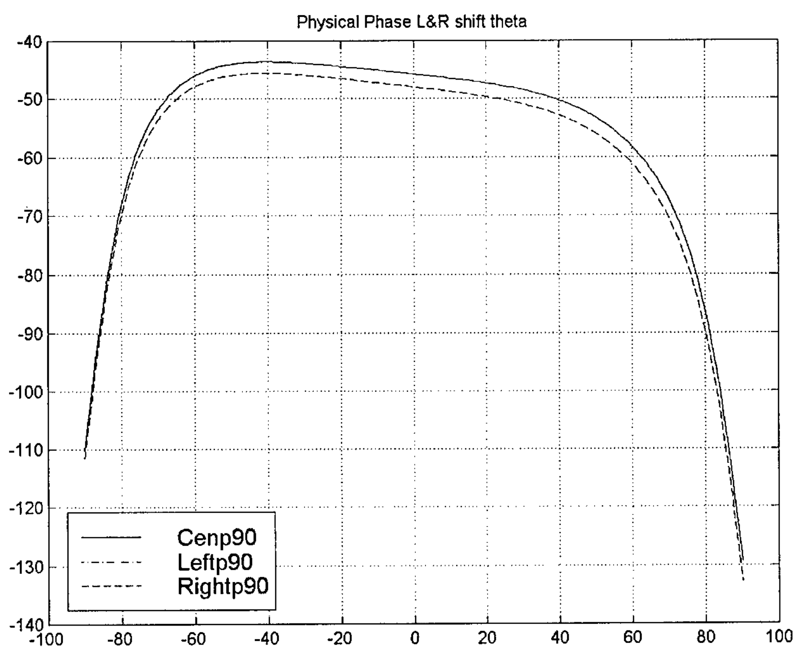


Figure 8 Variation of phase with shift in the left to right orientation E theta plane.

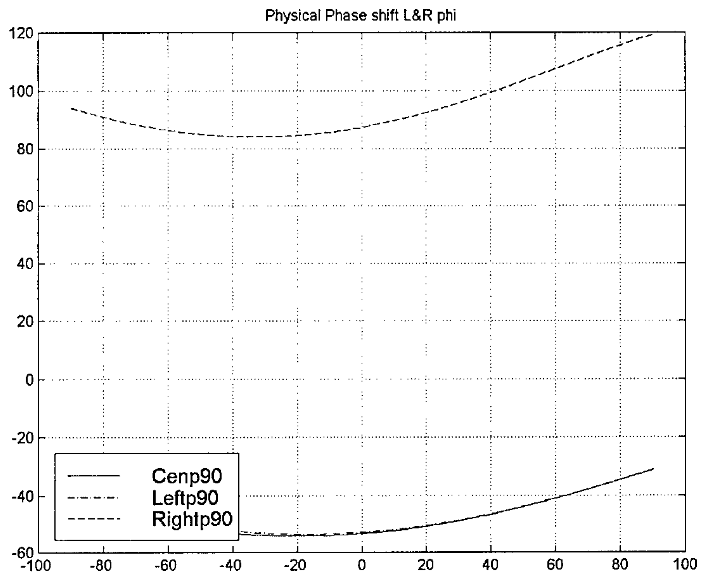


Figure 9 Variation of phase with shift in the left to right orientation E phi plane.

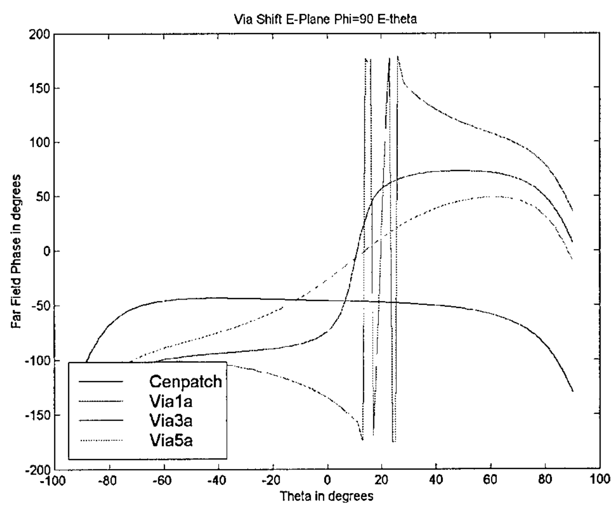


Figure 10 Effect of vias position on the far field phase in the E-theta plane.

The following conclusions can be drawn from the above data

- Placement of a via causes a far field phase shift
- The phase shift is similar to what occurs when the patch is physically moved in the simulator.
- This may be due to a shift of the phase center of the patch antenna.

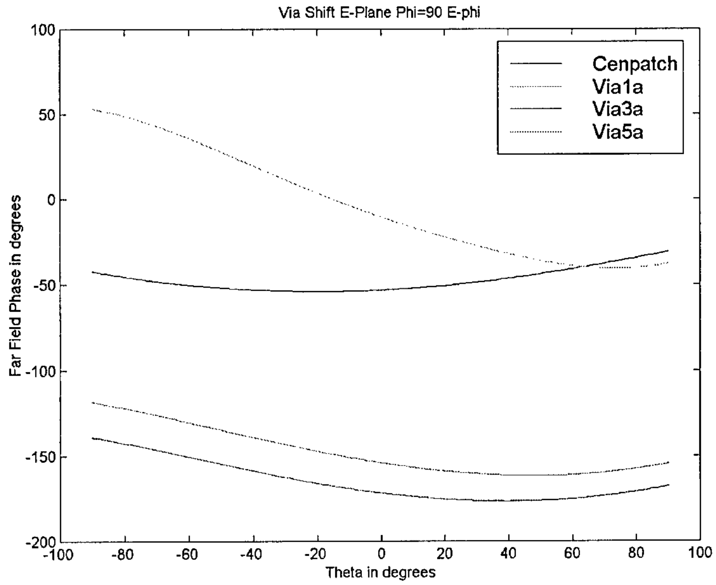
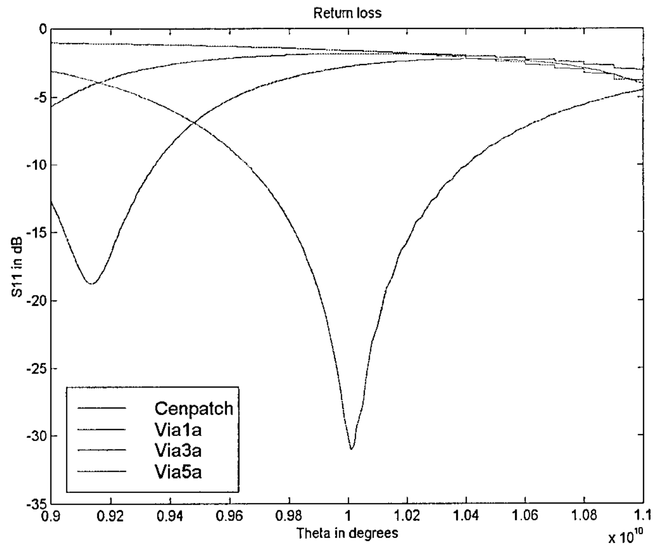
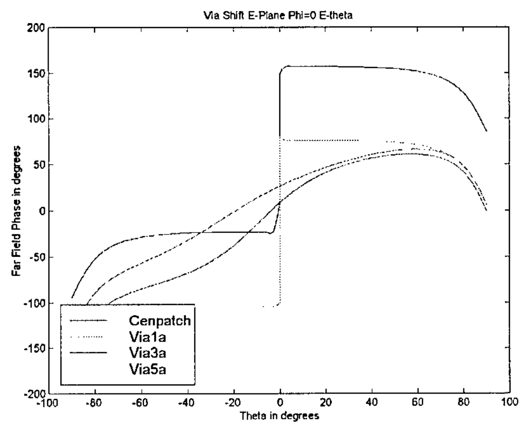


Figure 11 The variation of phase with three via locations.

Furthermore the following observations can be made,

- The shift appears to be greatest near the edges and towards the corners.
- When the via is symmetrically centered the shift is quite small. If pairs of vias are placed symetrically with respect to the y-axis the shift is quite small.
- If a via is placed along the x-axis, where the voltage null occurs, the effect is minimal.
- Where the greatest phase shift occurs, the greatest change in S11 occurs.


Return loss
S11 in dB
Theta in degrees
x 10^10
Cenpatch
Via1a
Via3a
Via5a


Via Shift E-Plane Phi=0 E-theta
Far Field Phase in degrees
Theta in degrees
Cenpatch
Via1a
Via3a
Via5a

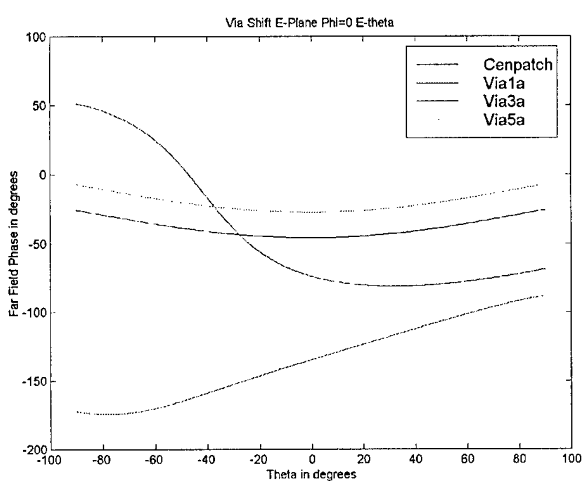

Via Shift E-Plane Phi=0 E-theta
Far Field Phase in degrees
Theta in degrees
Cenpatch
Via1a
Via3a
Via5a

Figure 14

The effects of ther cross polarization yield the following

- Inserting a via in the patch can produce a far field phase shift.
- The greater the phase shift
    - The greater the cross-pole
    - This was seen both in simulation and experimentally

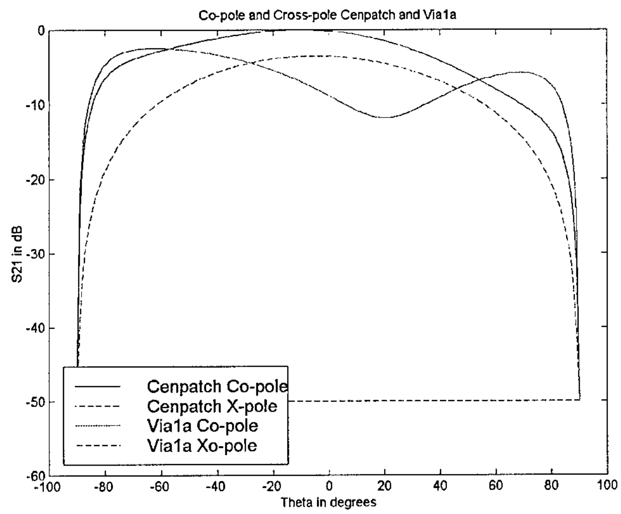


Figure 15

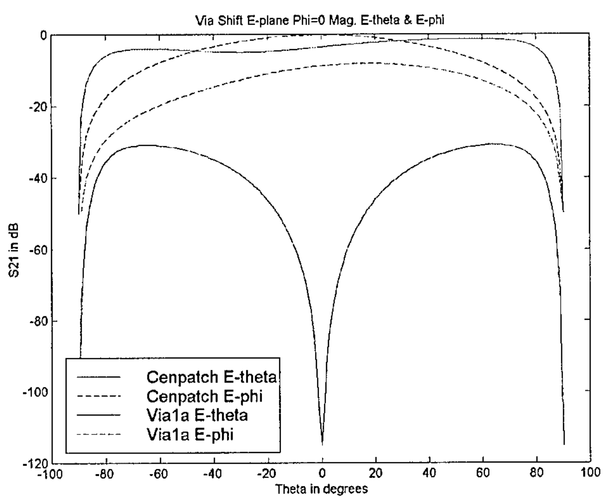


Figure 16

- Passing in the E-plane copole and crosspole components magnitude are effected identically due to via placed at either corner
- H-plane components suffer reduced gain at the corner opposite the via
- A symetric pair have a more even pattern due to addition

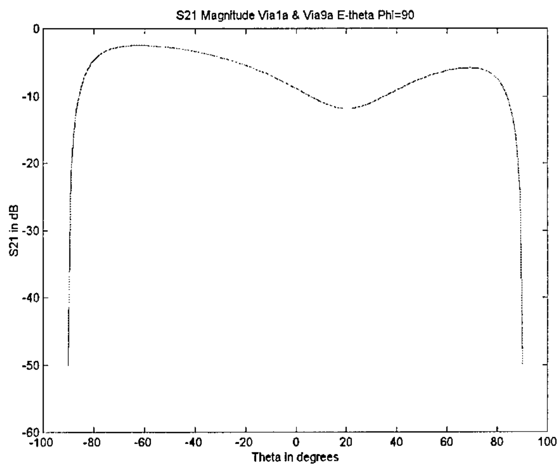


Figure 17

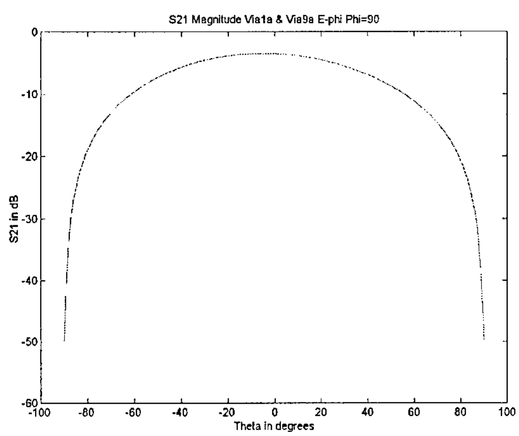


Figure 18

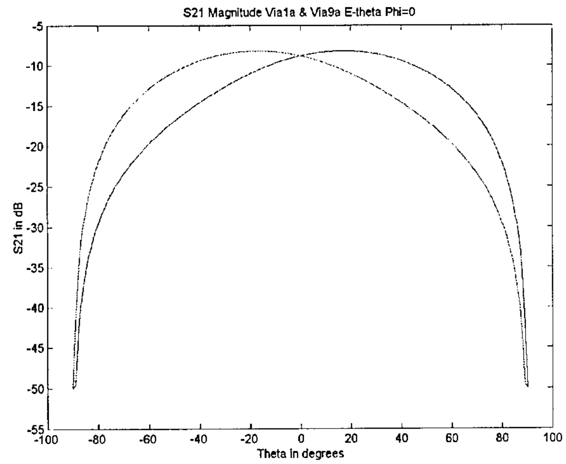


Figure 19

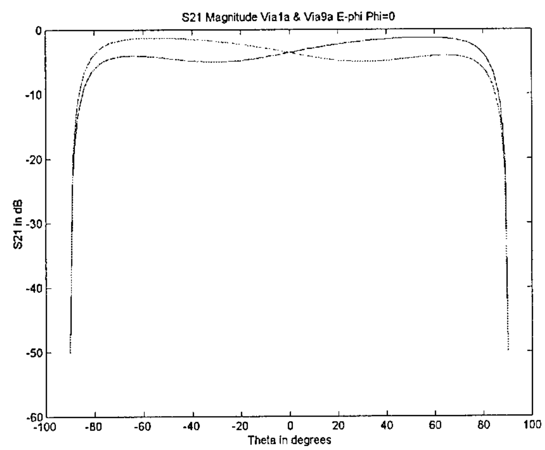


Figure 20

- Addition of a via causes a far field phase shift
- Cross polarization occurs proportionally to shift
- Input impedance is adversely affected proportionally to shift
- Adding symmetric vias reduces or eliminates the phase shift
- Location of the via toward higher current regions of the patch increases phase shift
- It appears the placement of a single via to achieve far field phase shift disrupts usual current flow along the patch causing an apparent phase center shift and resulting in the ff phase shift.

Conclusions

•Addition of a via causes a far field phase shift
–Cross polarization occurs proportionally to shift
–Input impedance is adversely affected proportionally to shift
–Adding symmetric vias reduces or eliminates the phase shift
–Location of the via toward higher current regions of the patch increases phase shift
–•It appears the placement of a single via to achieve far field phase shift disrupts usual current flow along the patch causing an apparent phase center shift and resulting in the far field phase shift.
–